LEAK CHECKING LANSCE STACK SAMPLING SYSTEMS

Purpose

This Meteorology and Air Quality Group (MAQ) procedure describes the steps to ensure that LANSCE stack sampling systems are free of significant leaks.

Scope

This procedure applies to the particulate and gas sampling systems at TA-53 monitored stacks, ES-2 and ES-3.

In this procedure

This procedure addresses the following major topics:

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11/05/04

General information

Attachments

This procedure has the following attachments:

Number	Attachment Title	No. of pages
1	Hazard Review	2
2	Derivation of Leak Check Calculation	3

History of revision

This table lists the revision history and effective dates of this procedure.

Revision	Date	Description Of Changes
0	7/26/93	New document, issued as MP-7-OP-9-5.01, “Procedure for Leak Checking Lines at LAMPF stacks”
1	6/1/98	Reformatted for LANSCE-FM document control; content revised and expanded to reflect current operations; issued as 53FMP 104-12.1 Attachment 1 included to derive calculations & equations used in analysis.
2	11/5/04	Reformatted to MAQ format; contents revised to reflect current operations.

Who requires training to this procedure?

The following personnel require training before implementing this procedure:

- Personnel assigned to the LANSCE stack monitoring effort

Training method

The training method for this procedure is **on-the-job** training by a previously-trained individual and is documented in accordance with the procedure for training (MAQ-024).

General information, continued

Prerequisites

In addition to training to this procedure, the following training is also required prior to performing this procedure:

- TA-53 Site Specific training (required for unescorted TA-53 access)
- TA-53 Limited Access Area training for certain experimental areas
- Radiological worker training as appropriate for different areas
- HCP-MAQ-TA53-XA (Experimental Area Access)
- HCP-MAQ-TA53-MI (Maintenance and Instrumentation)
- Basic Fall Protection course number 1307 (for those climbing scaffolding)
- Scaffolding user training course number 14708 (for those climbing scaffolding)

Definitions specific to this procedure

Facility operation: Memo ESH-17:96-291, "Sampling and Reporting Requirements for LANSCE," dated July 9, 1996, defines emissions monitoring and reporting requirements for TA-53. Sampling for particulate & vapor activation products must be carried out at all times. Gaseous emission monitoring from ES-3 and diffuse monitoring of the beam switchyard must occur when any beam is delivered to the switchyard or beyond. When beam is delivered down Line A, diffuse monitoring must occur for designated areas. When beam is delivered down Line D, gaseous emissions monitoring at ES-2 must take place.

References

The following documents are referenced in this procedure:

- MAQ-024, "Personnel Training"
- MAQ-601, "Collecting and Processing Stack Air Particulate and Vapor Samples from TA-53"
- 40 CFR 61 Appendix B, Method 114, Paragraph 4.7, Table 2
- 40 CFR 60 Appendix A, Method 5, Paragraph 4.1.4, "Leak-Check Procedures"

Note

Actions specified within this procedure, unless preceded with "should" or "may," are to be considered mandatory guidance (i.e., "shall").

Introduction

Description and requirements

The monitored stacks at the Los Alamos Neutron Science Center (LANSCE), located at Los Alamos National Laboratory (LANL) Technical Area 53, are designated TA-53-BLDG-7-ES-2 and TA-53-BLDG-3-ES-3. For simplicity, the stacks are referred to in this procedure as “ES-2” and “ES-3,” respectively.

Requirements for leak rate testing

To ensure proper analysis of TA-53 stack emissions, the air samples must reach the monitoring equipment without significant dilution. This dilution would result from fresh air being mixed with the sample air stream due to a leak in the sampling system. This procedure details the methodology used to detect any significant leaks in the sampling system.

A significant leak rate is defined as one in excess of 4% of the sample flow or 0.02 cubic feet per minute (whichever is less), as referenced in 40 CFR Part 60, Appendix A, Method 5, Section 4.1.4, “Leak Check Procedures,”. Due to the sample flow rates at LANSCE stacks (2 cfm and above), system leak rates must be maintained at less than 0.02 cubic feet per minute (0.0057 cubic meters/minute).

An annual leak check of the stack sampling systems is required by 40 CFR 61 Appendix B, Method 114, Paragraph 4.7, Table 2.

Preparation and system description

Possible contamination

The internal components of the stack sampling systems may be contaminated with radioactive material. To mitigate this hazard, the time interval between the end of the previous beam-operating period and the leak check should be maximized, still allowing sufficient time to resolve any problems that may be detected during this leak check before the next beam operating period.

Temperature effects

A significant portion of the sample lines is located outside of TA-53 buildings, so the temperature effects can expand or contract the air in the systems and lead to errors in analysis. Avoid performing leak checks during exceptionally warm or cold periods when such temperature effects could be significant. In all cases, be sure to include proper correction factors for stack air temperature and ambient pressure.

Leak test method

The “standard” leak check measures the leak rate of the entire sample line, associated gauges, sampling units, etc. The check is done by creating a vacuum from the sample probe to the inlet of the associated sample line pump, and monitoring the pressure rise over time.

At ES-3, the whole system can be checked by plugging the end of the probe. At ES-2, the sample line is separated and plugged at the connection to the probe. This checks the majority of the system volume and associated gauges, leaving only the sample probe outside the analyzed volume. Due to the construction of the probe, it is unlikely that leaks would occur in this area. It is more likely that leaks would occur at the sample system gauges and valves—areas that are all within the analyzed volume.

Changes to test method

In addition to checks of the entire system, it may be desirable at times to analyze only a small portion of a sample system, such as when the system setup is changed for special measurements. In this case, the methods described in this procedure can still be applied to a smaller section of the total system volume. Thoroughly record any such changes, the volume sampled, and analysis steps in the applicable logbook.

Access to probes

At ES-3, the probes are readily accessible from the ES-3 stack pad; at ES-2, however, scaffolding is required to access the probes near the top of the stack. The use of the scaffolding is covered in MAQ-618.

Preparation and system description, continued

Required equipment

The pump used for pulling air through the sample system can be used for the leak test. The pumps are equipped with a sample inlet valve and "fresh air" inlet valve. Other required equipment:

- anti-C gloves to be worn while handling probes or internal components of sample lines
- mechanical vacuum gauge, typical readout 0-100 inches of water, permanently installed in sample line
- stopwatch
- thermometer (each stack has a thermometer already monitoring stack air which can be used for this analysis)
- appropriate stack logbook to record readings
- rubber stoppers to plug the system probes or sample lines

ES-3, gas system probe	#4 rubber stopper
ES-3, particulate/vapor system probe	#2 rubber stopper
ES-2, gas system sample line	#3 rubber stopper
ES-2, particulate/vapor sample line	#8 rubber stopper

- Vacuum grease to assist in sealing the rubber stoppers in the probe tips or sample line (as needed)

Describe system

In the logbook, thoroughly describe the sampling system being analyzed. Draw a diagram of the system and record the volume in the logbook (if the system is identical to previous measurements, reference logbook pages rather than reproduce extensive diagrams and/or volume calculations).

Leak testing sample lines

Using this procedure

This procedure will normally be performed whenever probes are inspected in accordance with Procedure MAQ-618, *Stack Sampling System Inspection*. However, it is possible to perform this procedure by itself (without physically disconnecting the sample lines) by closing valves in the sample lines.

Turn off pump before plugging line

Before plugging or valving off the sample lines from the probe, unplug or turn off sample pump to avoid damage to pump and sample lines while system volume is sealed.

Steps to determine leak rate

If necessary, install a vacuum gauge into the sampling system. Follow the steps below:

Step	Action
1	Either valve off the sample line to the pump, or put a stopper in the disconnected sample line or probe end in accordance with MAQ-618.
2	Using the sample system pump, draw a vacuum inside the sample system. The fresh air inlet valve may be adjusted as needed regulate the vacuum.
3	When the desired vacuum (typically 40–50 inches of water) has been reached, close the pump inlet valve and disconnect the pump power (unplug it).
4	Record the vacuum pressure on the system and the stack air temperature.
5	Start the stopwatch.
6	Monitor the pressure and temperature over time, recording each parameter periodically.
7	After 10 minutes, record the final pressure and temperature.

Calculate leak rate

The leak rate, Q_{actual}, can be calculated from the change in vacuum pressure due to leakage of air into the evacuated system (as derived in Attachment 2). A simplified form of the equation to find the leak rate is as follows (derivation is in Attachment 2):

Leak testing sample lines, continued

$$Q_{actual} = \left[\frac{P_{start}}{T_{start}} - \frac{P_{stop}}{T_{stop}} \right] * \frac{V_{system}}{\Delta t * 42.2} * \frac{1\,\text{atm}}{P_{actual}} * \frac{T_{actual}}{273\,\text{Kelvin}}$$

where:

Q_{actual} volumetric leak rate of system, in actual cubic feet per minute.

P_{start}, P_{stop} pressure at start and end of analysis (measured in **inches of water <u>vacuum</u>**)

T_{start}, T_{stop} stack air temperature at start and end of analysis (converted to **Kelvin**). To convert from Fahrenheit to Kelvin, add 459.7 to the Fahrenheit temperature, then divide the sum by 1.80.

V_{system} volume of sample system, in **liters**; measure prior to analysis, or reference past analyses, accounting for any system modifications since last measurement

Δt time of analysis in **minutes** (typically 10 minutes)

P_{actual} ambient atmospheric pressure, measured in **atmospheres**, during test (typically about 0.77 atm for Los Alamos, reference the "LANL Weather Machine" for more accurate data)

T_{actual} ambient outside air temperature, measured in **Kelvin**, during test (again, reference "LANL Weather Machine" for accurate data)

[liters * inch H_2O] / [Kelvin * ft^3]. Unit conversion constant, incorporating ideal gas constant and unit conversion factors.

Acceptable leak rates

As stated earlier, the acceptable leak rate criteria is 0.02 actual cubic feet per minute. Leak rates less than this amount are considered acceptable. If the measured leak rate is greater than this amount, check the fittings of the rubber stoppers, any loose connections between gauges and sample lines, and other possible locations. Fix the leaks, then perform the test again.

If unacceptable leak rates continue, take action as necessary to fix the leaks and bring the leak rate within acceptable parameters. Record all results and steps performed in the stack logbook.

Records resulting from this procedure

Records

The following records, or copies thereof, generated as a result of this procedure are to be stored or submitted **within 4 weeks of completion** as described below:

- Documentation of system leak checks for the ES-2 and ES-3 stacks. This documentation is recorded in the logbook for the appropriate stack. Additional documentation for fixing leaks, etc., as necessary recorded in the logbooks or appropriate binder.
- A Memorandum for each stack reporting the results of the leak test and probe inspection with distribution to:
    - LANSCE-FWO
    - LANSCE-DO
    - RRES-MAQ Project Leader
    - Rad-NESHAP Team Members
    - Rad-NESHAP File
    - RRES-MAQ File

HAZARD REVIEW

Work tasks/Steps	**Hazards, Concerns, and Potential accidents**	**Controls, Preventive Measures** *(e.g., safety equipment, administrative controls, etc.)*	**Hazard Level** *from IMP 300-00-00 Hazard Grading Matrix*
Task as described in MAQ-616, R2 chapter *Leak testing sample lines*.	Cuts, scrapes, pinches. Hazard: low	Wear leather gloves; use common sense, remain undistracted. Facility-specific hazards—Have appropriate training.	Low

DERIVATION OF LEAK CHECK CALCULATIONS

The stack sampling/monitoring systems at TA-53 have their leak rates measured prior to each beam operation period. The sample line is plugged with a rubber stopper (preferably at the probe tip) and a vacuum is drawn on the system to a desired value. The valve at the pump inlet is then closed, sealing the system. Using ideal gas law, the number of moles of gas (air) inside the system is calculated as follows:

$$P * V = n * R * T$$

$$n = \frac{P * V}{R * T}$$

where: P = pressure of system
V = volume of system being analyzed
n = number of moles of air in the system
R = ideal gas constant, 0.08206 L*atm/(mol Kelvin)
T = temperature of system

The pressure and temperature of the system is monitored over a desired time length. The number of moles of air in the system at the start and finish of analysis can be calculated from the above equations; the difference between these two values is the amount of air that leaked into the system during the analysis. From this change in the number of moles, the corresponding change in volume of air in the system can be determined, assuming “standard-conditions” of 1 atmosphere ambient pressure and 273 Kelvin. This “standard volume” change can be converted to an actual volume change using actual ambient pressure and temperature data. This actual change in volume is then divided by the time of analysis to find the actual volumetric leak rate. Finally, this actual volumetric leak rate can be compared with acceptance criteria to determine if the system has a sufficiently low leak rate. The mathematical version of this process is described below.

To calculate the leak rate, the following system-specific data are needed:

P_{start}, P_{stop}	pressure at start and end of analysis (measured in **inches of water <u>vacuum</u>**)
T_{start}, T_{stop}	air temperature at start and end of analysis (converted to **Kelvin**). To convert from Fahrenheit to Kelvin, add 459.7 to the Fahrenheit temperature, then divide the sum by 1.80.
V_{system}	volume of sample system, in **liters**; measure prior to analysis, or reference past analyses, accounting for any system modifications since last measurement
Δt	time of analysis in **minutes** (typically 10 minutes)

Additionally, the following constants and relationships will be used in the analysis

R	ideal gas constant, R = 0.08206 L*atm/(mol*K)
407	inches of water per atmosphere
22.4	liters of air per mole of air at standard temperature and pressure (STP); referred to as the molar gas volume
28.3	liters per cubic foot

As described above, the difference in moles of gas in the system is first determined. Note that while the number of moles in the system is increasing with time (leaking into a vacuum), the vacuum pressure of the system is decreasing, which leads to the sign convention described below:

$$\Delta n = n_{start} - n_{stop}$$

$$\Delta n = \frac{P_{start} * V_{system}}{R * T_{start}} - \frac{P_{stop} * V_{system}}{R * T_{stop}}$$

$$\Delta n = \left[\frac{P_{start}}{T_{start}} - \frac{P_{stop}}{T_{stop}} \right] * \frac{V_{system}}{R}$$

Again, the vacuum of the system is recorded in inches of water. To balance units, the conversion between inches of water and atmospheres must be included, as follows:

$$\Delta n = \left[\frac{P_{start}}{T_{start}} - \frac{P_{stop}}{T_{stop}} \right] * \frac{V_{system}}{R} * \frac{1\,\text{atm}}{407\,\text{in.H}_2\text{O}}$$

Next, using the molar gas volume at standard temperature and pressure, one can determine the corresponding change in volume of air that entered the system from this change in the number of moles. The result will be ΔV_{STP} , the change in volume at standard temperature and pressure. Also, the units of volume are converted from liters to cubic feet.

$$\Delta n\,[\text{mol}] * \frac{22.4\,\text{L}}{\text{mol}} * \frac{1\,\text{ft}^3}{28.3\,\text{L}} = \Delta V_{STP}\ [\text{cubic ft at STP}]$$

To correct the change in volume from standard conditions to actual conditions at Los Alamos, the following data are needed. These data are available from the LANL Weather Machine, maintained by ESH-17.

P_{actual}	ambient atmospheric pressure during test (typically ~ 0.77 atm for Los Alamos; check LANL Weather Machine for more accurate data during day of test)
T_{actual}	ambient air temperature during test (check LANL Weather Machine for data)
V_{actual}	volume of sample at ambient conditions.
T_{STP}	273 Kelvin, “standard temperature” of gases
P_{STP}	1 atmosphere, “standard pressure” of gases
V_{STP}	volume of sample at “standard” temperature and pressure conditions.

To convert a volume at standard temperature and pressure to an actual volume at ambient temperature and pressure, one uses a combination of Boyle’s Law and Charles’ Law, as follows:

$$\frac{P_{actual} * V_{actual}}{T_{actual}} = \frac{P_{STP} * V_{STP}}{T_{STP}}$$

therefore

$$\Delta V_{actual} = \Delta V_{STP} * \frac{P_{STP}}{P_{actual}} * \frac{T_{actual}}{T_{STP}} = \Delta V_{STP} * \frac{1\,\text{atm}}{P_{actual}} * \frac{T_{actual}}{273\,\text{K}}$$

Dividing the change in volume (actual) by the time of analysis, one calculates the volumetric flow rate, Q_{actual}.

$$Q_{actual} = \frac{\Delta V_{actual}}{\Delta t}$$

where:

Q_{actual} volumetric flow rate of system, in actual cubic feet per minute. This is the final parameter for which we are solving.

The complete solution for the volumetric leak rate, Q_{actual}, in actual cubic feet per minute (acfm) is:

$$Q_{actual} = \left[\frac{P_{start}}{T_{start}} - \frac{P_{stop}}{T_{stop}}\right] * \frac{V_{system}}{R * \Delta t} * \frac{1\,\text{atm}}{407\,\text{in. water}} * \frac{22.4\,\text{L air}}{1\,\text{mole air}} * \frac{1\,\text{ft}^3}{28.3\,\text{L}} * \frac{1\,\text{atm}}{P_{actual}} * \frac{T_{actual}}{273\,\text{Kelvin}}$$

While the sampling systems at TA-53 are not subject to regulations in 40 CFR 60, the criteria for leak testing described in 40 CFR 60, Appendix A, Method 5 are used to determine if the sampling systems are sufficiently leak-tight. This criteria states, "Leakage rates in excess of 4 percent of the average sampling rate or 0.00057 m^3/min (0.02 cfm), whichever is less, are unacceptable." Since the sample flows at TA-53 are at least 2 cfm, the criteria of 0.02 cfm is used to determine the acceptability of leak rates.

<u>Shortcuts to above equation:</u>

To simplify the formula, all the constants in the above equation (R, the pressure conversion, mole to liter conversion, and volume conversion) can be combined together into a single constant, 42.2 [L * inches water]/[ft^3 * K].

$$Q_{actual} = \left[\frac{P_{start}}{T_{start}} - \frac{P_{stop}}{T_{stop}}\right] * \frac{V_{system}}{\Delta t * 42.2} * \frac{1\,\text{atm}}{P_{actual}} * \frac{T_{actual}}{273\,\text{Kelvin}}$$

Since the system air temperature does not greatly vary (on the Kelvin scale) during a 10 minute leak test, one can define $T_{system} = T_{start} = T_{stop}$, and this term can be removed from the initial parentheses. The pressure difference within the sample system can likewise be removed from the parentheses, and referred to as ΔP. The resulting equation for actual leak rate, in units of "actual cubic feet per minute" is:

$$Q_{actual} = \frac{\Delta P * V_{system}}{T_{system} * \Delta t * 42.2} * \frac{1\,\text{atm}}{P_{actual}} * \frac{T_{actual}}{273\,\text{Kelvin}}$$

To simplify this equation even further, one can include a typical temperature and pressure conversion factor in the constant. This typical value of the pressure & temperature correction factor can be calculated by assuming ambient Los Alamos atmospheric pressure of 0.77 atm (a typical value) and temperature of 20 degrees Celsius (293 K).

$$Q_{actual}\ [\text{acfm}] = \frac{\Delta P * V_{system}}{T_{system} * \Delta t * 30.3}$$

Again, the pressure difference is in inches of water, the system volume in liters, the system air temperature in Kelvin, and the time of analysis in minutes. The resulting flow rate is in actual cubic feet per minute (acfm).